

# Baffle Type Energy Dissipator for Pipe Outlets

By Vito A. Vanoni and James T. Rostron

(Concluded from the August issue)

ALL OF the information needed to design a pipe outlet structure is summarized in Figs. 7 and 8 by means of graphs, sketches, and formulas. In arranging this information it has been assumed that the design discharge is determined by field conditions only and that the width of the structure is fixed within limits by conditions at the site. The main points in the design are discussed below with a view to clarifying them and facilitating their application.

## DESIGN FORMULAS

**Fundamental Hydraulic Formulas.** The design formulas are expressed in terms of the two fundamental hydraulic variables,  $F_0$ , the velocity head factor, for the pipe flow, and  $d_c$ , the critical depth for the width,  $W$ . The first of these is expressed by

$$F_0 = \frac{V_0^2}{gD_0} = \frac{16Q_0^2}{\pi^2 g D_0^5} \quad [1]$$

where the expression on the right is obtained by introducing the equation,

$$V_0 = \frac{Q_0}{A_0} = \frac{Q_0}{\frac{\pi D_0^2}{4}}$$

$d_c^*$  is given by the familiar expression

$$d_c = \sqrt[3]{\frac{Q_0^2}{W^2 g}} \quad [2a]$$

Substituting  $Q_0$  from equation [1] into equation [2a] gives

$$d_c = D_0 \left( \frac{\pi}{4} \times \frac{D_0}{W} \right)^{2/3} F_0^{1/2} \quad [2b]$$

The energy equation for the system may be written in the form

$$E = (K_e + K_f + K_m + 1) \frac{V_0^2}{2g} + b_0 \quad [3a]$$

where  $E$  is the total available head, and  $K_e$ ,  $K_f$ , and  $K_m$  are respectively, the loss coefficients for entrance, friction in the pipe, and miscellaneous causes. By substituting  $b_v$  for  $V_0^2/2g$  and by estimating average values of the loss coefficients and the back pressure,  $b_0$ , equation [3a] becomes

$$b_v = 0.3E \quad [3b]$$

Lacking better information, this is a good value of  $b_v$  to use in making the first trial calculation to determine  $D_0$ . The method of calculation is shown in detail under "Design Example."

**Formulas for Baffle-Box Dimensions.** All of the dimensions of the baffle box are defined by Figs. 1 and 7 and their values are given as formulas in Fig. 7. These dimensions have been assigned lower limits that are determined by practical, hydraulic, and structural considerations. For instance, the minimum value of the baffle height,  $b_1$ , is such that sufficient room is allowed to turn the jet issuing from the pipe. It is easy to see that this value must be more than the pipe diameter, and the minimum value of  $1.5D_0$ , determined by experiment, therefore appears reasonable.

**Formula for Back Pressure on the Pipe.** The formula for back pressure is based on the equation

$$b_0 = b_1 + \frac{V_2^2}{2g} \quad [8]$$

where  $V_2$  is the velocity through the gap between the cap and the headwall.  $V_2$  may be taken as

$$V_2 = \frac{Q_0}{WKd_c} \quad [8a]$$

where  $K$  is a numerical factor which varies with the velocity head factor and the width ratio of the structure. Introducing [8a] into [8] gives

$$b_0 = b_1 + \frac{1}{K^2} \times \frac{Q_0^2}{2W^2 d_c^2 g} \quad [8b]$$

Analysis of the data on back pressure showed that the coefficient,  $1/K^2$ , could be expressed as

$$1/K^2 = 4.0 \times (W/D_0)^{-0.41} F_0^{-0.05} \quad [8c]$$

Introducing this equation into equation [8b] and dividing through by  $D_0$  gives

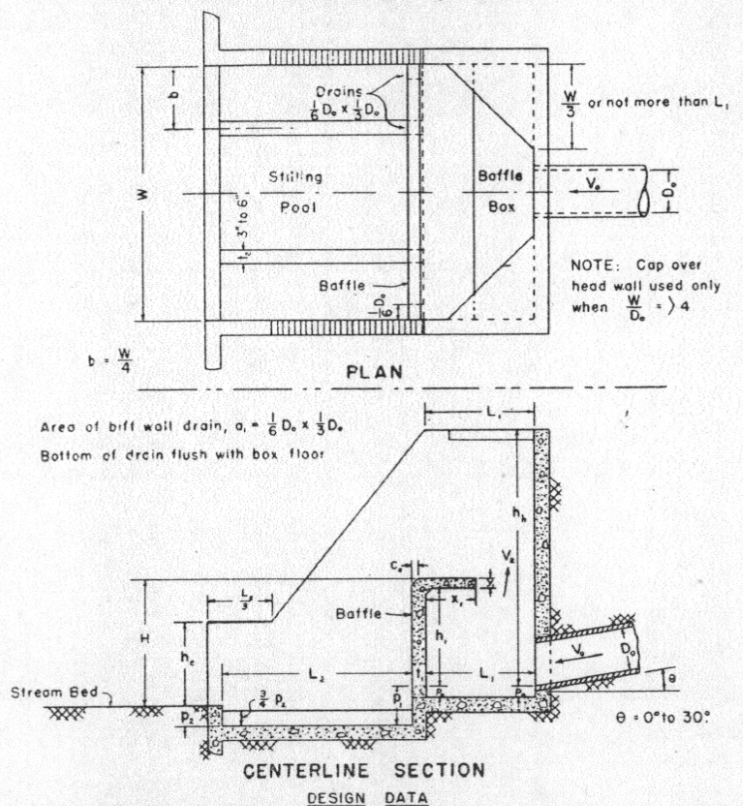
$$\frac{b_0}{D_0} = \frac{b_1}{D_0} + 4.0 (W/D_0)^{-0.41} F_0^{-0.05} \times \frac{Q_0^2}{2W^2 d_c^2 g D_0} \quad [8d]$$

Introducing equations [1] and [2a] gives

$$b_0/D_0 = 2(W/D_0)^{-1/2} + [1.5 + 2.0 (W/D_0)^{-0.41} F_0^{-0.05}] \times [\pi/4 \times D_0/W]^2 F_0^{1/2} \quad [8e]$$

## PIPE OUTLET STRUCTURE - FLOOR BAFFLE TYPE

(Based on the Laboratory Program, 1942)



### DESIGN DATA

$Q_0$ ,  $E$ , and  $W$  determined by field conditions. For first trial design calculate  $b_v$  from equation (3b) to obtain  $V_0$ ,  $D_0$ ,  $F_0$  and  $\frac{W}{D_0}$ , and then get  $\frac{b_0}{D_0}$  from chart (b).

$Q_0$  = Design Discharge in cfs.

$Q_1$  = Discharge thru drains =  $0.2 Q_0$  approx

$L_1 = 3.0 d_c$ ;  $L_{1(min)} = 2.0 D_0$

$b_1 = h_0 + d_c$  (9);  $b_1 = 3.0 d_c$  (10)

$h_1 = 2 D_0 \left( \frac{W}{D_0} \right)^{1/2} + 1.5 d_c$ ;  $h_{1(min)} = 1.5 D_0$

$L_2 = C_v \sqrt{H d_c}$  (Standard Drop Design) (15)

$x_1 = 0.5 h_1$ ;  $(L_1 - x_1)_{(min)} = 18"$

$c_{e(max)} = 0.51$ ;  $c_{i(max)} = 0.3 x_1$  (amount of fillet under cap)

$y$ , and  $t$ , to be determined by structural requirements

Fig. 7.

\*R. L. Daugherty, "Hydraulics," pp. 285-7, McGraw-Hill, New York, 1937.

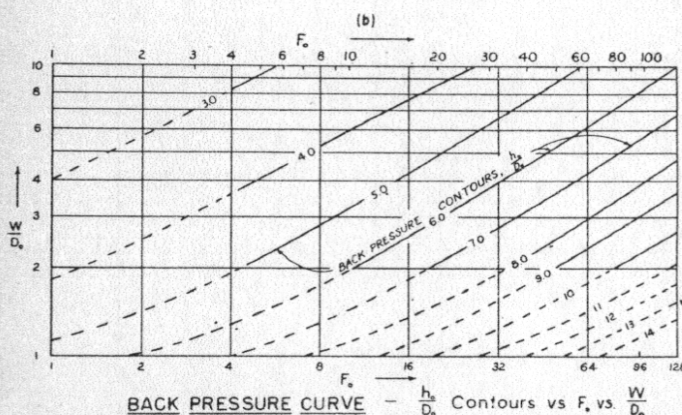
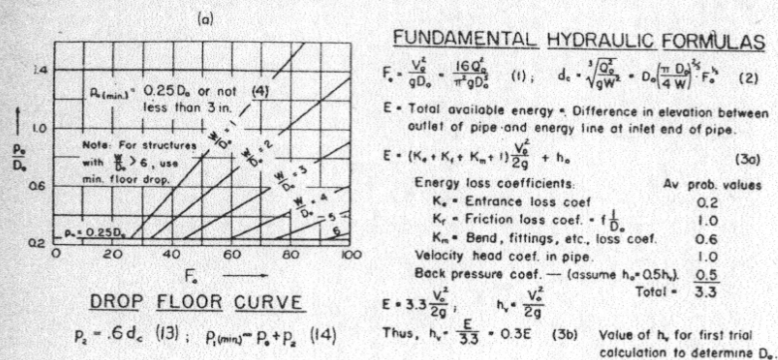
The curves of Fig. 8(b) were calculated from this equation.

**Formulas for Sidewall Dimensions.** The height,  $h_h$ , of the headwall given by equation [9] in Fig. 7 is sufficient to give adequate freeboard. Since the height of the water surface above the floor of the box is very nearly equal to  $h_0$ , the freeboard provided is equal to  $d_c$ . The depth of water over the end sill was found to be about  $2d_c$ . Therefore, by making the height of the wall at this point equal to  $3.0d_c$ , a freeboard of  $d_c$  is provided at this point also. The other sidewall dimensions shown in Fig. 7 were determined by experiment.

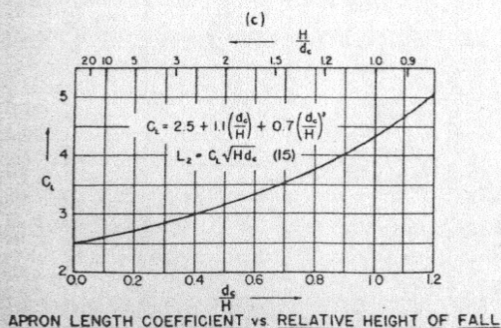
Splash caps over the corners formed by the headwall and sidewalls are to keep water which rises in the corners from overtopping the walls. They are found necessary only in wider structures since in narrow structures there is no tendency for the water to rise higher near the sides than at the center of the headwall. Splash caps are used on structures with width ratios of 4 or greater. Their effectiveness in increasing the safe overload capacity may be seen in Fig. 9 which shows a structure operating at an overload of about 40 per cent.

**Formulas for Stilling Pool Dimensions.** The formulas for the stilling pool dimensions follow those developed by Morris and Johnson<sup>†</sup> for the gully control drop. The length,  $L_2$ , of the pool which is given by equation [15] is taken directly from the gully

<sup>†</sup>Hydraulic Design of Drop Structures for Gully Control, B. T. Morris and D. C. Johnson. Trans. Am. Soc. C. E., v. 69, 1943, pp. 887.



$$\frac{h_2}{D_0} = 2 \left( \frac{W}{D_0} \right)^{-1/2} + \left[ 1.5 + 2.0 \left( \frac{W}{D_0} \right)^{-1/2} \right] \left[ \frac{\pi D_0}{4W} \right]^{1/2} F_0 \quad (8a); \quad h_2 = h_1 + \frac{V_0^2}{2g} \quad (8)$$



NOTE: \* Contours of chart (b) obtained from the solution of eq. (8a).

### DESIGN CHARTS for PIPE OUTLET STRUCTURE FLOOR Baffle TYPE

Fig 8

drop. The value of the length coefficient,  $C_L$ , is given by curve (c) of Fig. 8. The depth of the pool,  $P_2$ , is made  $0.6d_c$  (equation [13]) since according to experiments this value gave the best performance. This depth is 20 per cent greater than in the gully drop and is required to handle the more severe conditions resulting mainly from flow through the drains in the baffle. Two longitudinal sills of height  $3/4 P_2$  are placed at the quarter points as shown in Fig. 7.

In order to prevent silting of the baffle box, the top of the end sill of the stilling pool should not be higher than the floor of the box. However, the pool can be lowered as much as desired as long as its length is made according to equation [15].

**Drains through Baffle.** On the basis of experiments and practical considerations, the four drains through the baffle were made  $1/6 D_0$  wide by  $1/3 D_0$  high. As shown in Fig. 7, two of the drains are placed flush with the side walls and two are at the quarter points. The bottom of all the drains is placed flush with the baffle box floor.

**Structural Dimensions.** In the laboratory study, no attempt was made to determine structural dimensions of any of the walls. However, pressures which must be resisted by the structure were measured in the baffle box. For design purposes it will be satisfactory to assume a uniform pressure over the entire baffle equal to  $0.25 (h_0 + h_v)$  and a pressure head acting over an area of  $D_0$ , opposite the pipe outlet equal to  $0.75 (h_0 + h_v)$ . The pressure head on the headwall and sidewalls may be assumed to vary linearly from  $h_0$  at the base to zero at a distance of  $h_0$  feet above the base.

The resultant unit pressure on the cap may be assumed as  $0.2 (h_0 + h_v)$  acting over the entire underside of the cap in the upward direction. It is probable that most of the structural dimensions will be fixed by earth-pressure loads and by considerations other than water pressure.

To prevent chipping and cracking of the exterior corner at the intersection of the baffle and cap, it is desirable to chamfer the corner. The effect of the chamfer on flow conditions is merely to increase effectively the length of the stilling pool by the amount of the chamfer because the crest of the fall is moved upstream by that amount. Hence, the maximum value of the chamfer,  $c_1 = 0.5t_1$ , specified in Fig. 7, is based entirely on practical and structural reasons, and therefore this value may be varied. It was shown by experiment that the fillet,  $c_1$ , at the intersection of the wall and the cap can be made as much as  $0.3x_1$  without appreciably affecting the performance of the structure.

### DISCUSSION OF RESULTS

**Effect of  $W/D_0$  on Baffle Box Dimensions.** The width ratio determines the proportion of the flow which is deflected upward or toward the sidewalls by the baffle and consequently plays an important part in fixing the dimensions of the baffle box. Formulas [4], [5], [6] and [7] show that as the width is increased and more of the flow is turned sideways the baffle can be lowered and placed nearer to the outlet. It also may be seen that the structure size increases slowly with an increase in flow capacity. Since the flow pattern is not affected by the velocity head factor until the water has reached the free surface above the baffle cap, the baffle-box dimensions are not strongly influenced by the discharge rate. When the discharge is increased considerably, only a small increase is required in the size of the baffle box to provide satisfactory performance. Consequently a particular structure will operate successfully over a considerable range of discharges, up to the design flow of the structure. Thus in the design equations the baffle-box dimensions are a function of  $W$  and  $D_0$  primarily and of  $F_0$  to a lesser degree. The effect of the width ratio on the flow pattern and design dimensions is illustrated in Fig. 10. Both structures are designed for the same discharge.

In contrast it may be stated that other types of energy dissipation structures, such as those employing the hydraulic jump, require a considerable increase in size when the discharge (Continued on page 344)





## Back to Elm Street, U. S. A.

Back from the business of killing—to the business of living!

Back from scenes of hatred, despair and destruction to a homeland of peace, hope and opportunity!

Millions of young Americans are coming back to thousands of farms—to thousands of peaceful Elm Streets in every city, town and village of America!

They've made up their minds to a lot of things while they've been away.

They've seen the suffering of homeless terrorized families—people who have lost their self-respect, their hope, their health—*everything*.

They've seen a large part of the world in ruins, because a few fanatical men sold "gold bricks" to millions of people who traded in their freedom

for promises of security—for brightly painted pictures of a "planned economy" under an all-wise, all-powerful government.

And they want no part of that sort of thing here in America.

They want jobs. They want to plan their own lives. Make their own futures. Go places under their own power.

And we must give them that opportunity.

But to do it, wartime restrictions and controls must be removed from agriculture, business—and the individual citizen—as quickly as possible.

Farmers must be free to plant what they want, and as much as they want—without needless bureaucratic supervision.

Taxes must be adjusted so that money will be available to finance the change-over to peacetime production.

Greater incentives must be provided, so that workers can make *more* money, by making *more* goods for *more* people.

Mr. Private Citizen must be allowed to make money—and be free to invest it in business ventures of his own—or of others.

Prosperity has always come to America through the *growth* of production—not its restriction—on farms and in factories.

Profitable production *will make jobs* for the boys who are coming back. But business, labor, agriculture and an *understanding* government must *work together* to create it—hold it—and increase it.

BUY  
WAR BONDS  
AND  
STAMPS  
—AND KEEP  
THEM!



The Army-Navy flag waves over 7 Republic plants and the MaritimeM floats over the Cleveland District plant.

# REPUBLIC STEEL

GENERAL OFFICES: REPUBLIC BUILDING, CLEVELAND 1, OHIO

Export Department: Chrysler Building, New York 17, New York

WOVEN WIRE FENCING • BARBED WIRE • STEEL FENCE POSTS • BALE TIES  
ROOFING and SIDING • NAILS • STAPLES • BOLTS, NUTS and RIVETS • PIPE  
CARBON, ALLOY and STAINLESS STEELS for FARM and DAIRY EQUIPMENT



(Continued from page 342)

## GLOSSARY OF TERMS

- $b$  = distance from sidewalls to centerline of longitudinal sills in stilling pool, ft  
 $b_1$  = width of drain opening, ft  
 $C = \left( \frac{\pi}{4} \times \frac{D_0}{W} \right)^{2/3}$  = a critical depth coefficient  
 $c_e$  = exterior chamfer of baffle, ft  
 $c_f$  = fillet at corner formed by cap and baffle, ft  
 $C_L$  = stilling pool apron length coefficient  
 $C_L$  = Coefficient of energy loss  
 $D_0$  = Diameter of pipe outlet, ft  
 $d_c = \sqrt[3]{Q_0^2 / W^2 g}$  = critical depth, ft  
 $E$  = a specific energy, ft-lb per lb  
 $\Delta E$  = loss of energy, ft-lb per lb  
 $f$  = friction factor for pipes  
 $F_0 = V_0^2 / g D_0$  = velocity head factor  
 $g$  = gravitational acceleration, ft/sec<sup>2</sup>  
 $H$  = net drop from baffle crest to stream bed, ft  
 $h_e$  = entrance head loss, ft  
 $h_f$  = friction head loss, ft  
 $h_L$  = total losses in pipe leading to structure, ft  
 $h_e$  = height of end wall, ft  
 $h_h$  = height of head wall, ft  
 $h_0$  = back pressure head on pipe outlet, ft  
 $h_v = V_0^2 / 2g$  = velocity head of flow in pipe, ft  
 $h_1$  = net height of baffle, ft  
 $K$  = coefficient in back pressure equation  
 $K_e$  = loss coefficient for entrance  
 $K_f$  = loss coefficient for pipe friction  
 $K_m$  = loss coefficient for miscellaneous causes  
 $L_1$  = length of baffle box, ft  
 $L_1'$  = top length of side wall, ft  
 $L_2$  = length of stilling pool, ft  
 $L_2'$  = horizontal sidewall dimension for stilling pool, ft  
 $L_s$  = overall length of structure, ft  
 $l$  = length of pipe carrying discharge to structure, ft  
 $p_0$  = drop in floor of baffle box below pipe invert, ft  
 $p_1$  = drop of stilling pool floor below pipe invert, ft  
 $p_2$  = depth of stilling pool (height of transverse or end sill)  
 $Q_0$  = design discharge, cfs  
 $Q_1$  = discharge through baffle drains, cfs  
 $t_1$  = thickness of baffle, in  
 $V_c = \sqrt{g d_c}$  = critical velocity, ft/sec  
 $V_0$  = velocity of flow at pipe outlet, ft/sec  
 $V_1$  = velocity of flow discharging from baffle box, ft/sec  
 $V_2$  = velocity in downstream channel, ft/sec  
 $W$  = width of structure, ft  
 $x_1$  = overhang of baffle cap, ft  
 $y_1$  = thickness of cap, ft  
 $\theta$  = slope of inlet pipe, deg

becomes materially greater, and also require greater structure lengths with increasing values of  $W/D_0$  because of the distance required for the spreading of the high velocity jets issuing from the pipe outlets before the formation of a jump is possible.

## Fitting Structure to Field Conditions.

From a study of the design data and charts of Figs. 7 and 8, it becomes clear that this structure is designed to operate under con-

ditions of relatively high velocity discharge. As an example, assume that a structure with a 1-ft pipe is designed for a factor,  $F_0$ , of 16. Then from equation [1] the velocity head is 8 ft and the velocity and flow in the pipe are 22.7 fps and 17.8 cfs, respectively. Even with this relatively small velocity head factor and small pipe, the velocity and discharge are high.

On the back-pressure chart, Fig. 8 (b), the solid lines indicate the range of conditions under which the structure is most efficient and economical. The dashed lines give the back pressure for narrow structures with low velocity head factors. These structures generally are less economical than those in the range covered by the solid lines. For instance, if field conditions indicate that an extremely narrow structure is desirable, it may be possible to effect a saving in total cost by using a wider structure even though the excavation costs may be increased. The main factors in this saving are reductions in wall height and structure length. Structures with width ratios of approximately 6 appear to be the most economical. However, the optimum width depends largely upon field conditions, and therefore must be determined by the designer. Although structures designed according to the charts will operate satisfactorily, it is probable that simpler and cheaper structures can be devised when velocity head factors are below 8.

The pipe size for a system including a baffle-energy dissipator is calculated as it would be for any pipe line which has a submerged outlet. The amount of the submergence is equal to the back pressure created by the installation of the structure, and its value is given by curve (b) in Fig. 8. However, before the back pressure can be determined,  $F_0$ , and therefore the diameter of the pipe, must also be known. In designing a structure, several trial calculations are usually required before the correct size of pipe is determined. To reduce to a minimum the number of trials required, average probable values of the losses have been assumed and an equation [3b] obtained which gives a value of  $h_v$  for the first trial calculation to determine  $D_0$ . It should be noted that once the pipe diameter is determined, the discharge can be increased on a given installation only by increasing the total head. This can be done only by raising the water level over the inlet to the pipe. Since the inlet is usually a box forebay or small reservoir with limited freeboard, the water surface, and therefore the total head, cannot be raised to any great extent. Practically, this means that it is not possible appreciably to overload a pipe outlet structure and in designing this feature must be kept in mind.

**Construction and Maintenance Considerations.** In fixing the dimensions of the baffle box, it was necessary not only to give consideration to the hydraulic performance of the structure, but also to keep in mind other practical requirements. For instance, the gap between the baffle and the head-wall was made sufficiently large so that the flow was not throttled. In the smaller structures this gap may become quite small, making it difficult to build the box and to clean it out if that becomes necessary. Therefore, in order to provide room for construction and cleaning of the box the gap was made 18 in minimum.

(Continued on page 346)

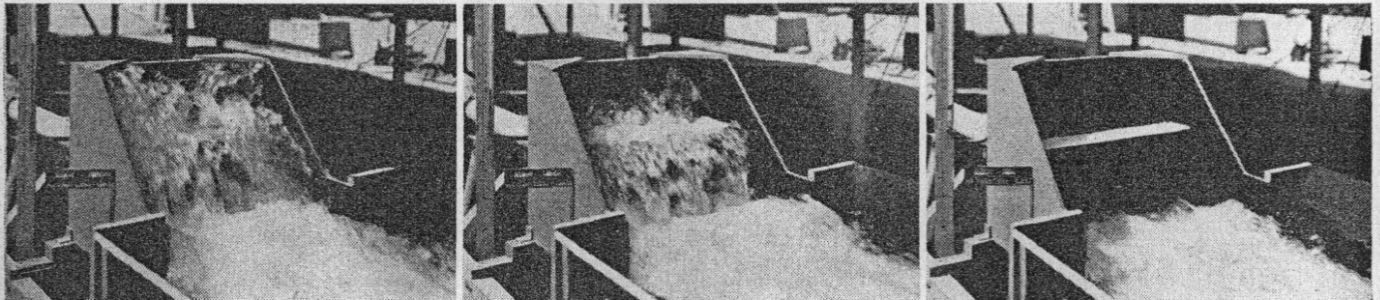


Fig. 9 (Left) Model structure discharging a 40 per cent overload showing the action of the splash caps at the corners in preventing the walls from being overtopped • Fig. 10 (Center) Effect of width ratio on flow pattern and design dimensions. Both structures designed for a velocity head factor of 16. (a) (Top center) Narrow structure operating at 0.83 of design discharge.  $D_0 = 3$  in;  $W/D_0 = 3.0$ ;  $p_0 = 0.33D_0$ ;  $L_1 = 3.2D_0$ ;  $h_1 = 3.0D_0$ ;  $x_1 = 1.5D_0$ ;  $h_0 = 5.2D_0$ ;  $h_h = 6.7D_0$ ;  $L_2 = 5.2D_0$ ;  $p_2 = 0.66D_0$ . (b) (Bottom center) Normal width structure operating at design discharge.  $D_0 = 3$  in;  $W/D_0 = 6.0$ ;  $p_0 = 0.33D_0$ ;  $L_1 = 2.0D_0$ ;  $h_1 = 2.1D_0$ ;  $x_1 = 1.0D_0$ ;  $h_0 = 3.8D_0$ ;  $h_h = 4.7D_0$ ;  $L_2 = 3.4D_0$ ;  $p_2 = 0.41D_0$  • Fig. 11 (Right) Low flow in model showing all of discharge passing through drains in baffle. This prevents clogging of the pipe by debris-laden flow



East elevation of Roy Spar farm tenant house, Ada, Ohio.

# Farm Tenant House of the Present and the Future



George R. Shier  
Consulting Agricultural Engineer

George R. Shier  
Consulting Agricultural Engineer  
Howard S. Sterner Company  
Columbus, Ohio

"Mr. and Mrs. Roy Spar have lived on their farm near Ada, Ohio many years. When Mr. Spar's growing seed corn business and other farm activities required full-time help they decided to construct an attractive tenant house that would help to secure an intelligent tenant family.

"The present farm labor shortage has helped justify their foresight. When help is difficult to obtain they are able to offer living quarters better than those occupied by the majority of farm owners. Yet the house is simple in construction, as evidenced by the fact Mr. Spar did the carpenter work himself with the aid of farm labor. The plans were prepared by the Department of Agricultural Engineering, Ohio State University.

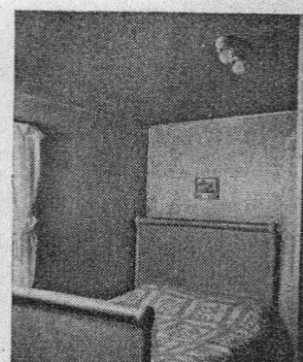
"Interior type plywood finished with a clear 'Floor seal' has provided attractive wall and ceiling surfaces in kitchen, hall, bath and three bedrooms. Two rooms were plastered at Mrs. Spar's request to avoid monotony, but she now feels that all plywood walls would have been preferable. The house is now three years old and the plywood still presents an attractive finish, while the other walls are beginning to show the need for redecoration. When the natural wood walls do need refinishing this can be accomplished with stain, paint, or wallpaper without initial preparatory treatment."



View of north end of kitchen showing home-made cabinet work. Penetrating floor seal used for natural wood finish.



Opposite end of kitchen showing electric range and modern dining set. Plywall panels placed horizontally and nailed to native rough lumber framing by unskilled labor.



Rear downstairs bed room with plywood panels placed vertically on walls. Framing headers cut between studs behind all horizontal panel joints.

Post-war farm tenants will desire better living conditions. The new farm houses to be built then will not be "miracle houses" but comfortable, durable houses in the traditional manner using the best of the new materials proved by the war emergency.

Douglas fir plywood's ease of handling and fabrication are especially appreciated by the rural builder. The wide range of decorative possibilities with commonly available materials is a boon to the amateur painter. The "shock-resistance" and the ease of refinishing are especially important in the tenant house.

War labor housing in all sections of the United States, and Army and Navy hutments both here and abroad have proved the dependability of plywood housing. Speed of erection, adaptability to simple design and weather resistance under all climatic extremes are features which mean improved housing for the farm tenant family of the future.

## Brief Specifications:

Size—1½ story, 6 room

Erected—Winter 1941-42

Builder—Owner and farm labor. Skilled labor required for plastering.

Framing—Conventional, with framing members placed behind all plywood joints.

Interior walls and ceilings—¼" Ply-wall grade. Douglas fir plywood placed vertically or horizontally directly on studding and nailed with 4d nails 6" on center. Panels butted and glued under the joints with urea resin adhesive.

Kitchen cabinet—¾" Plypanel grade Douglas fir plywood built in place by owner.

Finish on plywood—One coat of clear penetrating floor sealer.

**DOUGLAS FIR PLYWOOD ASSOCIATION**  
Tacoma 2, Washington

**PLYWALL D.F.P.A.**  
TRADE MARK REG. U. S. PAT. OFF.

**GENUINE PLYWALL**  
TRADE MARK REG. U. S. PAT. OFF.  
Douglas Fir Plywood  
**WALLBOARD**  
D.F.P.A. INSPECTED

**GENUINE DOUGLAS FIR PLYFORM**  
TRADE MARK REG. U. S. PAT. OFF.  
Concrete Form Panel  
D.F.P.A. INSPECTED

**GENUINE PLYSCORD SHEATHING**  
TRADE MARK REG. U. S. PAT. OFF.  
D.F.P.A. INSPECTED

**EXT. - D.F.P.A.**  
TRADE MARK REG. U. S. PAT. OFF.

**DOUGLAS FIR PLYWOOD**  
**LARGE. LIGHT. STRONG.**  
*Real Wood*  
**PANELS**

Farm Buildings are War Equipment  
—Keep them Fit and Fighting!

**SPECIFY DOUGLAS FIR PLYWOOD BY THESE "GRADE TRADE-MARKS"**



(Continued from page 344)

The four drains through the baffle are designed to prevent the box from filling up with sediment. Danger of clogging is greatest during the lower discharges when quiet flow in the box permits sediment to deposit. By making the drains as shown in Fig. 7, they will discharge approximately 20 per cent of the flow when the structure is operating at design discharge. Laboratory experiments showed that with drains of this size the box was self-cleaning and could handle heavily laden flows without undue hazard from clogging. Fig. 11 shows the same model structure as in Figs. 9 and 10b operating at a discharge low enough to permit all of the flow to pass through the drains. It is seen that the stilling pool spreads the flow from the jets so that it discharges rather uniformly over the end sill.

Experiments showed that the performance of the baffle box was improved by dropping the floor slightly below the invert of the pipe. The dimension,  $p_0$ , in Fig. 7, is given by the curves of Fig. 8(a). It will be noted that the minimum value of  $p_0$  is  $0.25D_0$ . For practical reasons it is recommended that this dimension be made not less than 3 in. This will facilitate the construction and also improve drainage of the pipe and baffle box during low flows.

TABLE 1. DESIGN CALCULATIONS

Design Data		Trial 1	Trial 2	Trial 3	Trial 4	
Quantity	Equation	(Hydraulic Design)				
$Q_0$	cfs	Field	40.0	40.0	40.0	
$E$	ft	Field	26.0	26.0	26.0	
$W$	"	Field	9.0	9.0	15.0	
$h_v$	"	[3b] or $V_0^2/2g$	7.80	7.95	7.95	9.95
$V_0$	ft/sec	$\sqrt{2gh_v}$	22.4	22.6	22.6	25.3
$A_0$	ft <sup>2</sup>	$Q_0/V_0$	1.78	1.77	1.77	1.58
$D_0$	ft	Pipe diameter	1.51	1.50	1.50	1.42
						(or 17 in)
$F_0$		[1]	10.2	10.6	10.6	14.0
$W/D_0$		Width ratio	5.96	6.0	4.0	10.6
$h_0$	ft	chart (b)	5.90	5.85	6.9	4.25
$h_t$	"	$f \times 1/D_0 \times h_v$	9.30	9.55	9.55	12.6
$h_e$	"	$0.2h_v$	1.55	1.6	1.6	2.0
$E'$	"	$h_v + h_0 + h_t + h_e$	24.6	25.0	26.0	28.8
		[3a]	(Baffle Box Design)			
$W$	ft	str. width	Estimated	9.00	6.00	15.0
$p_0$	"	chart (a)	value of	0.375	0.375	0.355
$C$	"	$(\pi/4 \times D_0/W)^{2/3}$	$h_v$ slight-	0.257	0.339	0.176
$d_c$	"	[2]	ly low.	0.85	1.11	0.605
$L_1$	"	[5]	Choose	3.00	3.33	2.84
$2D_0(W/D_0)^{-1/2}$	"		nearest	1.65	1.88	1.29
$1.5d_c$	"		standard	1.28	1.67	0.91
$h_1$	"	[6]	size pipe	2.93	3.55	2.20
$x_1$	"	[7a]	and recal-	1.46	1.78	1.10
$L_1 - x_1$	"	[7b]	culate all	1.54	1.60	1.74
$L_1$		[5] vs. [7b]	quantities			
			(Sidewalls and Stilling Pool Design)			
$h_0$	ft	Chart (b)		5.85	6.9	4.25
$h_h$	"	[9]		6.70	8.01	4.86
$h_e$	"	[10]		2.55	3.33	1.82
$p_2$	"	[13]		0.51	0.67	0.36
$p_1$	"	[14]		1.00	1.25	0.75
$y_1$	"			0.40	0.40	0.40
$H$	"	[16]		3.82	4.53	2.99
$d_c/H$				0.222	0.246	0.202
$C_L$		Curve (c)		2.75	2.80	2.70
$L_2$	ft	[15]		4.95	6.28	3.64
$W/4$	"	sills		2.25	1.50	3.75
$3/4 p_2$	"	"		0.38	0.50	0.27
$L'_1$	"	[11]		3.00	3.33	2.84
$L'_2$	"	$L_{3/4}$		1.65	2.09	1.21
$W/3$	"	Splash cap		3.00	2.00	2.84
Drains	in	[18]		$3 \times 6 \times t_1$	$3 \times 6 \times t_1$	$2 \frac{3}{4} \times 5 \frac{1}{2} \times t_1$
				1.0 draw-	Exact	2.8 ft rise
				down per-	check of	in w.s.
				mitted in	hydraulic	elev. re-
				reservoir	gradient	quired to
				26.0—25.0=1.0 ft	obtained	obtain $Q_0$

## DESIGN EXAMPLE

In order to clarify further the actual use of the design charts and equations, an example is presented. Assume that the following are established by field conditions:

- 1 Structure to be constructed at pipe outlet of an earth dam.
- 2 Design discharge,  $Q_0 = 40$  cfs
- 3 Total available head,  $E =$  height of reservoir water surface above center of pipe outlet  $= 26$  ft
- 4 Field conditions permit structure width from 6 to 15 ft
- 5 Length of pipe connecting reservoir and structure, 90 ft.

Following the procedure normally used for computing the size of a pipe line, the total available energy is equated to all of the losses in the system. Assumptions for values of the loss coefficients, usually have to be made in the first trial calculation. In computing the pipe size when a baffle-outlet structure is included, the back pressure or static head loss must also be considered. The energy equation [3a] for the system is given in Fig. 8 of the design charts, and a value of  $h_v$  for the first trial calculation of  $D_0$  is given by equation [3b].

A structure width of 9.0 ft, well within the limits stated in the assumption of field conditions, is chosen for the first trial design and a friction factor,  $f$ , of 0.02 is assumed for the pipe. The entrance loss is considered to be  $0.2h_v$ . To simplify the example, all other pipe line losses, such as those due to valves, elbows, etc., are neglected.

In Table 1 are listed some of the possible designs for a structure which will meet the above specified field conditions and in Table 2 complete computations are shown for the design listed as Trial 2. Photographs of models similar in appearance to the structures obtained in Trial Designs 2 and 3 are shown in Fig. 10.

TABLE 2. TRIAL DESIGN NO. 2

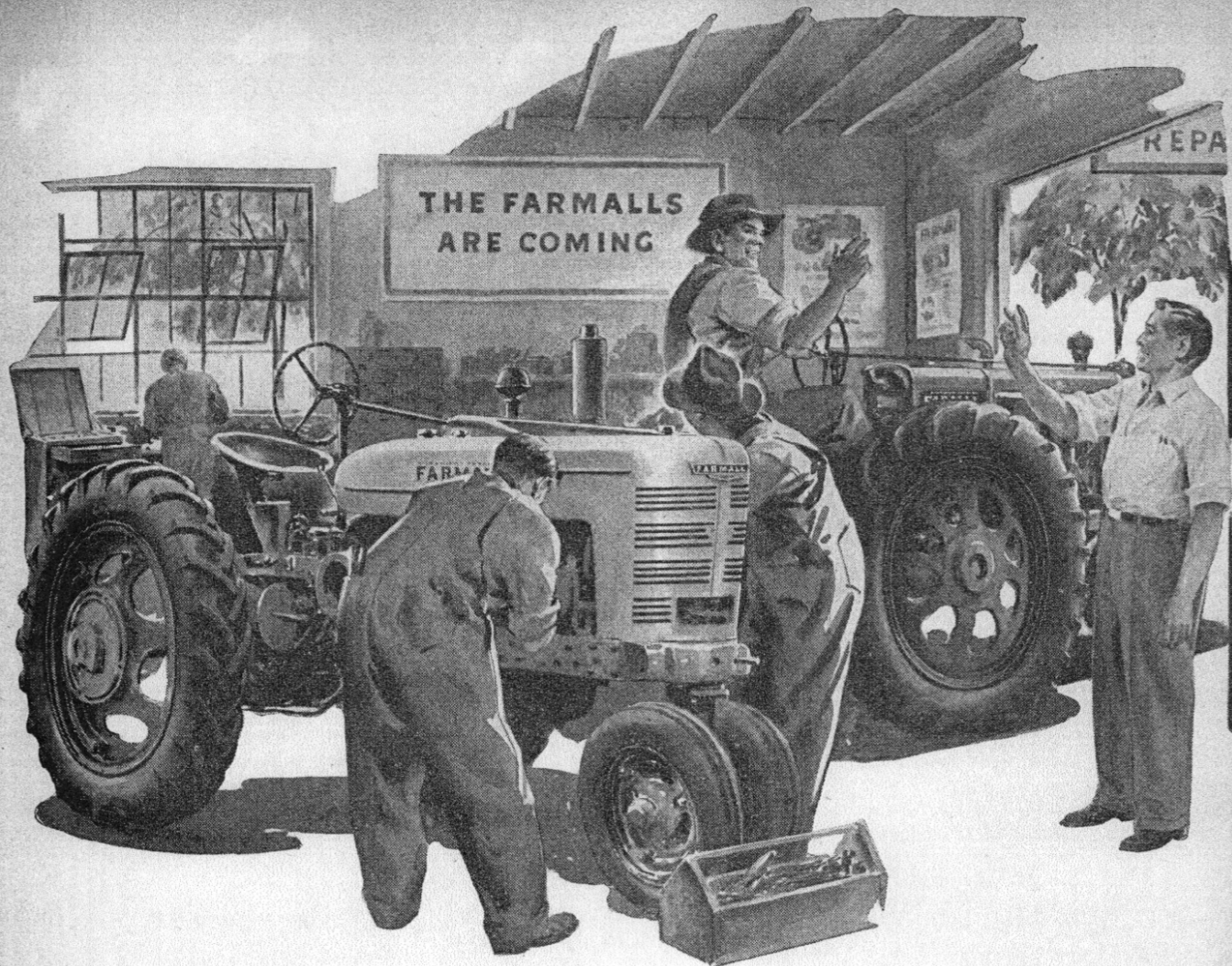
$Q = 40$  cfs;  $W/D_0 = 6.0$ ;  $E = 26.0$ ;  $D_0 = 18$  in;  $W = 9$  ft 0 in;  $l = 90$  ft

General data	Design formulas
$E = (K_e + K_f + 1) V_0^2/2g + h_0$	Baffle box dimensions
$V_0 = Q_0/A_0$ ; $A_0 = \pi D_0^2/4$	$p_0 = 0.25D_0 = 0.25 \times 1.5 = 0.375$ ft
$= 1.77$ ft	$L_1 = 3d_c$ or $2d_0$ ; $L_1 = 3 \times 0.85 = 2.55$ ft
$V_0 = 40/1.77 = 22.6$ fps	$L_1 = 2 \times 1.5 = 3.00$ ft
$h_v = V_0^2/2g = 7.95$ ft	$h_1 = 2D_0(W/D_0)^{-1/2} + 1.5d_c$
$F_0 = V_0^2/gD_0 = 2 \times 7.95/1.5 = 10.6$	$h_1 = 2 \times 1.5/(6)^{1/2} + 1.5 \times .85 = 2.93$ ft
	$x_1 = 0.5h_1 = 1.46$ ft
	$L_1 - x_1 = 3.00 - 1.46 = 1.54$ ft, o.k.
	Sidewall dimensions
$W/D_0 = 6.0$	$h_h = h_0 + d_c = 5.85 + .85 = 6.70$ ft
From chart (b) Fig. 9	$h_e = 3d_c = 3.0 \times .85 = 2.55$ ft
$h_0/D_0 = 3.9$	$L'_1 = L_1 = 3.00$ ft
$h_0 = 5.85$ ft	$L'_2 = L'_2 = 4.95/3 = 1.65$ ft
	(For $L'_2$ , see stilling pool dimensions)
$K_e = 0.2$	Stilling pool dimensions
$K_f = f(l/D) = 1.2$	$p_2 = 0.6d_c = .6 \times .85 = 0.51$ ft
Vel. head $= 1.0$	$p_1$ (min) $= p_0 + p_2 = 0.51 + .38 = .89$ ft
Loss Coeff. $= 2.4$	Make $P_1 = 1.00$ ft
	Assume $t_1 = 0.5$ ft, $y_1 = 0.40$ ft
$E' = 2.4 \times 7.95 + 5.85 = 25.0$ ft	$H = h_1 + y_1 + p_1 - p_2 = 2.93 + 0.40 + 1.00 - 0.51$
$E - E' = 26.0 - 25.0 = 1.0$ ft	$H = 3.82$ ft; $d_c/H = .85/3.82 = 0.222$
$=$ reservoir drawdown permitted	From curve (C) Fig. 9, $C_L = 2.75$
Critical depth, $d_c = \sqrt[3]{Q_0^2/W^2g}$	$L_2 = C_L \sqrt{Hd_c} = 2.75 \sqrt{3.82 \times .85} = 4.95$ ft
$d_c = \sqrt[3]{40.0^2/81.0 \times 1/32.2} = \sqrt[3]{0.615}$	Longitudinal sills, $b = W/4 = 2.25$ ft from sidewalls
$d_c = 0.85$ ft	Height of sills, $3/4 p_2 = 0.38$ ft
	4 drains: $1/6 D_0 \times 1/2 D_0 = 3" \times 6" \times t_1$
	Length of legs of splash caps, $W/3$ or $L_1$
	$= 9.0/3.0 = 3.00$ ft

In reference to these designs (Table 1), several points may be mentioned. In Trial 1 the assumed velocity head was slightly low, and consequently a larger pipe was obtained than was necessary to discharge the flow. However, its value was nearly correct so that the nearest smaller standard pipe size was used for Trial 2 and the hydraulic gradient was recalculated. This gave a satisfactory solution for the hydraulic design which utilized all but 1.00 ft of the total available head,  $E$ . Therefore, the design of the structure was completed by following the equations and charts of Figs. 7 and 8. Experiment showed that 87 per cent of the energy existing at the pipe outlet is dissipated in passing the flow through this structure.

Since the total available head was not entirely utilized, it is possible to make an alternate solution using a narrower structure, which will have a higher back pressure. (Continued on page 348)





## BETTER THAN ONE A MINUTE!

*In six months 5000 McCormick-Deering dealers repaired more tractors of all makes than International Harvester built in the three years before the war.*

That's putting power back on the land at an all-time record-breaking clip—one tractor every 50 seconds!

★ ★ ★

You men on farms know better than anyone what this service work has meant to war food production. When war cut farm machine production to almost nothing McCormick-Deering dealers lit into repair work on the greatest scale in history. The job they are doing now is winning a new place for them in the forces

fighting for food throughout the country.

More help is now on the way. The government has authorized increased production of Farmalls and Farmall equipment. We are building with all possible speed. But here's sthething to remember:

You're going to need all the equipment you have and all you can get for a long time to come. Keep your machines in first-class shape. McCormick-Deering dealers will help you. They operate the greatest farm equipment service and repair force in the nation.

Schedule your work now.



INTERNATIONAL HARVESTER COMPANY  
180 North Michigan Avenue Chicago 1, Illinois

# SERVICE WILL PULL YOU THROUGH!



(Continued from page 346)

The design listed as Trial 3 is one based on a structure width of 6.0 ft and a pipe diameter of 1.5 ft which gives a width ratio of 4.0 for the structure. In this design, the hydraulic gradient was checked exactly, i.e., the sum of the losses of the system was equal to the total available energy.

Trial 4 design was made assuming that a 17-in diameter pipe was available. Hence, to design a structure which will best fit the existing field conditions, it will be necessary to reduce the back pressure to a minimum since all other losses will be increased by using the smaller pipe. Therefore, 15 ft, the maximum possible structure width, is chosen for calculating the design. In this solution it was found that for design discharge the losses exceeded the total available head by 2.8 ft so that the dam height must be raised by that amount unless the freeboard is to be reduced. It is possible that the design discharge could be carried by a 17-in pipe if one having lower friction losses and an improved entrance could be used. The system as originally assumed will discharge 37.6 cfs, or  $0.94Q_0$  under a head of 26 ft.

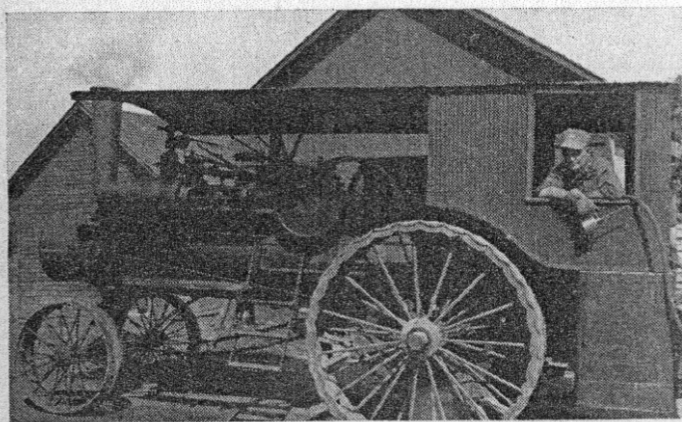
From the number of designs given to fit the assumed field conditions, it is evident at once that there is more than one satisfactory solution to the problem. Therefore, the design which must ultimately be chosen will be determined by an economic comparison, or by other considerations that are affected by the local conditions.

#### SUMMARY AND CONCLUSIONS

The pipe outlet structure described in this paper and developed through laboratory experiment is designed to dissipate high velocity flow from a pipe outlet so that it can be discharged safely into an erodible channel. A general design has been developed that will cover all combinations of rate of discharge, pipe diameter, and width of structure likely to be encountered in practice. Performance of the structure is such that flow discharging from the stilling pool is uniformly distributed across the width, thus presenting a favorable condition for erosion control at this critical point.

The dimensions of the baffle box in particular and the structure as a whole were worked out very carefully to determine the smallest possible structure that would give satisfactory performance. Changing any one or several of the dimensions results either in poorer performance or in increased cost. All the information necessary to design a structure is given by the drawing, formulas, and charts of Figs. 7 and 8.

**AUTHORS' ACKNOWLEDGMENTS:** The authors wish to acknowledge the friendly participation of Mr. J. G. Bamesberger, who visualized the field problem and was largely responsible for initiating the investigations, and of Mr. Karl O. Kohler, Jr., who kindly reviewed and criticized the results. Appreciation is also expressed for the friendly assistance and advice of Professor Robert T. Knapp and for the cooperation of the members of the staff of the Cooperative Laboratory. The laboratory investigation was started under the guidance of Mr. Brooks T. Morris, who was also responsible for designing the apparatus for the small scale tests.



## The Self Propelled Combine

(Continued from page 336)

type machine of the same size; and logically the narrower the cut, the greater the differential between each type of machine.

Our field experience and the information compiled from our tests indicate the importance of proper combine selection by a farmer in keeping with his requirements. A combine which has too narrow a cut for a given acreage will increase the cost per bushel of harvesting, as well as labor for handling. On the other hand, these costs must be balanced against the initial investment necessary for various types of machines available and the possible loss of grain, if he is dependent upon his neighbor or custom operators for his threshing job.

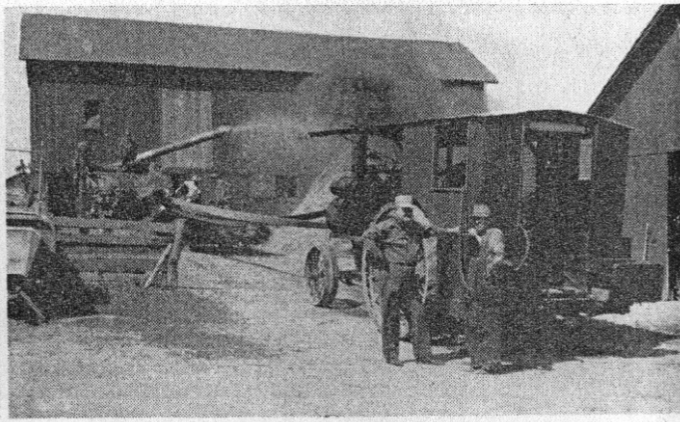
With opportunities now open to farm labor in urban industrial areas, at higher wages and shorter hours, the farmer has become more and more dependent upon his immediate family and modern equipment to produce his crops. If this situation continues, and indications are that it will, farmers will be faced more than ever before with the necessity of one-man operating equipment, and the larger operator may find it desirable and more economical to procure large single-purpose machines. The small farmer, if he is to compete with his produce, is similarly faced with an equipment problem, and since diversification is the basis for a successful operation we must have a complete line of tools expressly suited to his needs and his pocketbook. The small tractor with mounted equipment would seem to offer this small operator the most efficient equipment at the lowest initial investment.

Our country's success will continue to be dependent upon its ability to produce food economically, and our postwar period will place on our farmers greater demands for increased production. Future farm equipment must continue its advance in taking the hard work out of farming and thus make this occupation both profitable and pleasant.

## Emphasize Education

(Continued from page 327)

As a profession and as a Society we are well fitted to foster education. Something like half of our membership is or has been connected with the colleges. Our immediate A.S.A.E. past-president, in both talent and experience, is qualified to give well-balanced guidance to educational extension, and our current president is a man of notable energy and vision both in education and in engineering. Both the needs of the times and the leadership available suggest this as the moment to emphasize education.



1944 REMINDER OF WHEN STEAM POWER WAS IN FLOWER

"Where there's smoke, there's always fire," so instinctively argues W. H. Mitchell, chief of the St. Joseph, Michigan, fire department. The smoke in this instance, however, was harmless, but it led him on one of his rural jaunts last month to what is probably the last surviving steam threshing rig in southwestern Michigan, shown in these pictures — a Port Huron tandem compound steam engine and Goodison thresher owned by Arthur Brownell who has been threshing with steam power since 1910. "Mitch" — in the cab at the left, and who himself was a first-rate engine and "separator" man

a quarter century ago — happened along just at the right time to take over temporary operation of the rig for Mr. Brownell who was suffering from an injury. What memories this scene calls up for those who were boys on the farm before steam power made way for the more efficient, if less picturesque "gas" tractor! What a thrill used to come — and still does — from that odoriferous blend of steam, soft coal smoke, and threshing dust! And how some of us youngsters of yesteryear envy Mitch his opportunity again to "pull the throttle" on a steamer! — EDITOR